CLEOME ORNITHOPODIOIDES L. ON VANADIUM-SLAG
AT CANTON, BALTIMORE, MARYLAND
WITH NOTES ON THE BIOGEOCHEMISTRY OF VANADIUM

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The author (2-6) has published several lists of the plants found on the various ore piles in Canton, Port of Baltimore, Maryland and in Newport News, Virginia. In 1964, some 536 species were listed or described from these piles, most of them having been found on chrome ore, iron ore or manganese ore.

In 1962-63 a small pile of vanadium-slag was dumped along Clinton Street in Canton, and on this pile in 1963 about 25 specimens of Cleome ornithopodioides Linn. came up. Specimens collected on August 20, 1963 (Reed 65408; dupl. in US and U. Wisc.) were sent to Dr. H. H. Iltis, Department of Botany at the University of Wisconsin, where identification was verified. This species is new to the flora of North America.

The species came up again in 1964, spreading to cover the pile (about 10 ft. in diameter and 5 ft. high). Seedlings about 6 inches tall were transplanted for study. Some of these plants were in flower and even in fruit with ripe seeds at this time. (June 23, 1964, Reed 66675). The seedlings were potted in normal garden soil. However, the plants showed little growth for three weeks. Then, I added some of the fine vanadium-slag to the soil and watered it in. Within two weeks the plants were 1-1/2 to 2 feet tall, which equalled the heights of plants collected on the slag pile on August 14, 1964 (Reed 58183). Seeds from No. 58183 were sent to Dr. Iltis for further study.

Cleome ornithopodioides Linn. Native in the southern Balkans and the Near East. (Persia bor. et austr.; Tauria; Caucasus; Armenia; Anatolia, Smyrna; Russia).

An annual, up to 60 cm. tall, stems glandular-pubescent; leaves trifoliate, about 2.5 cm. long, including the 1 cm. petiole; leaflets oblong-linear; flowers white with a tinge of pink,

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1. Botanist, Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, Beltsville, Maryland.
2. Reed, Rhodora 56: 178-181. 1954.
3. Reed, Castanea 26: 123-127. 1961.
4. Reed, Castanea 26: 128. 1961.
5. Reed, Castanea 27: 59-61. 1961.
6. Reed, Phytologia 10(5): 321-406. 1964.

about 2-4 mm. in diameter; sepals sometimes with a blackish margin; stamens 6, free at the base; silique glandular-pubescent, 2-2.5 cm. long, with 9-10 black, smooth seeds. The seedlings start to flower about the fourth node above the ground. From specimens studied, collected on vanadium-slag pile in Canton, Baltimore, Maryland, in 1963 and 1964. Exact data recorded above.

Vanadium is not usually considered a micronutrient element for most plants. However, for Cleome ornithopodioides Linn., it seems to accelerate growth. Cannon(7) reported that Cleome integrifolia had up to 70 ppm. in the ash.

The most complete review of the biogeochemistry of vanadium until 1950 is that by Bertrand(8), in which the occurrence of vanadium in soil, animals and plants is thoroughly surveyed and critically evaluated. A fine bibliography for the subject is given. Several more recent works evaluate the tolerance, resistance, toxicity, accumulation, and nutrient value of vanadium in various types of plants.

Biebl(9) studied the resistance of plant plasm to vanadium, using solutions of $VOSO_4$ in percent solutions from 20 to 0.0001. Among the Bryophytes studies, these species could tolerate percent solutions up to the following: Mnium rostratum - 3.0; Mnium undulatum - 5.0; Mnium punctatum - 3.0; Plagiochila asplenioides - 3.0; Bazzania trilobata - 10.0; and Trichocolea tomentella - 5.0. Among our cultivated plants of economic value Solanum tuberosum could tolerate solutions 0.0001 or less; Solanum lycopersicum (Lycopersicum esculentum) Beta vulgaris subsp., Raphanus sativus, Daucus carota and Allium cepa, up to 0.001; Rheum rhabarbarum, and Brassica oleracea var. gongylodes, up to 0.01 Among some weedy plants tested, Polygonum lapathifolium, Atriplex patulum, Mercurialis annua, Atropa belladonna, Solanum nigrum, Datura stramonium, Senecio vulgaris, Helianthus annuus

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7. Cannon, Helen L. Effect of Uranium-Vanadium Deposits on the Vegetation of the Colorado Plateau. Amer. Jour. Sci. 250 (10): 735-770. Oct. 1952.

8. Bertrand, Didier. Survey of Contemporary Knowledge of Biogeochemistry. 2. The Biogeochemistry of Vanadium. Bull. Amer. Mus. Nat. Hist. 94: 403-456, tables 1-5. 1950.

9. Biebl, Richard. Ueber die Resistenz Pflanzlicher Plasmen gegen Vanadium. Protoplasma 39(2): 251-259, 2 tables. 1950.

and Artemisia campestris could withstand concentrations up to 0.001 percent. Among the plants usually cultivated for ornamental purposes, Begonia scharffiana (0.0001), Cyclamen persicum (0.001), Iris pallida (0.01), Iris florentina (0.001), Iris pumila (0.001), Iris trojana (0.01), Rhoeo discolor (1.0), Tradescantia purpusi (0.001) Tradescantia zebrina (0.0001) and Cephalanthera rubra (0.001) were resistant to solutions up to the given percentages.

Suzuki(10) found that the sulfate of vanadium in a culture medium having 100 ppm. was poisonous to barley. On the other hand, Kumar and Lall(11) found that in solutions of vanadium oxide up to 0.01 ppm. the vitamin C concentration increased in tomatoes, but the fruits became more sour. Chiu(12) found that growth was increased in rice seedlings by application to the nursery beds of solutions of vanadium oxide, with the best results at 150 ppm. Arnon(13) found increased growth in lettuce and asparagus when up to 0.001 ppm. of vanadium was added to the culture solution.

Among the lower plants vanadium plays an important role in the nitrogen fixation of Azotobacter species (14-17). The data

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10. Suzuki, S. On the action of vanadium compounds on plants. Tokyo Bull. Agr. 5: 515. 1903.

11. Kumar, K. and S. B. Lall. Effect of vanadium on chemical composition of tomato fruits. Indian Sci. Cong. Proc. 40(3): 118. 1953 (1954).

12. Chiu, T. F. The effect of vanadium application on the paddy rice. Agr. Res. 4(2): 48-59. Sept. 1953.

13. Arnon, D. I. Microelements in culture solution experiments with higher plants. Amer. Jour. Bot. 25: 322-325. 1938.

14. Konishi, Kametaro and Tsuge Toshihisa. Effect of inorganic constituents of soil solution on the growth of Azotobacter. Jour. Agr. Chem. Soc. Japan 9: 510-520. 1933.

15. Burk, D. and C. K. Horner. The specific catalytic role of molybdenum and vanadium in nitrogen-fixation and amide utilization by Azotobacter. Internat. Soc. Soil Sci., 3rd Congress, Trans. 1: 152-155. 1935.

16. Bore, J., Bore, C. and D. I. Arnon. Molybdenum and vanadium requirements of Azotobacter for growth and nitrogen fixation. (Abs.) Plant Physiol. 32(Sup.): xxiii. 1957.

pertinent to the effect of vanadium on nitrogen-fixing organisms is reviewed by Nason(18). Jensen and Spencer(19) studied the influence of vanadium on the nitrogen fixation by Clostridium butyricum and related organisms. Sampath(20) showed that sporulation in yeast cells was inhibited by 280 ppm. of vanadium, but was quite favorable with 140 ppm. Bertrand(21,22) showed that vanadium acted as a growth factor in concentration of 2×10^{-9}M for Aspergillus niger. Allen(23) found that vanadium could not be substituted for the molybdenum requirement of the blue-green alga, Anabaena. Among green algae, Arnon and Wessel(24) found that there was an 8-fold increase in the growth rates in the green alga, Scenedesmus obliquus, upon the specific addition of vanadium to the purified nutrient solution. Later, Arnon(25) reported that

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17. Becking, J. H. Species differences in molybdenum and vanadium requirements and combined nitrogen utilization by Azotobacteriaceae. Plant and Soil 16(2): 171-201. Apr. 1962.

18. Nason, Alvin. The metabolic role of vanadium and molybdenum in plants and animals. Chapter 19 in Trace Elements. 264-296. 1958.

19. Jensen, H. L. and D. Spencer. The influence of molybdenum and vanadium on nitrogen fixation by Clostridium butyricum and related organisms. Linn. Soc. N. S. Wales Proc. 72: 73-86. 1947.

20. Sampath, S. Effect of vanadium on yeast cells. Current Science (India) 13: 47. 1944.

21. Bertrand, D. Vanadium in plants. Bull. Soc. Chim. Biol. 23: 467-471. 1941.

22. Bertrand, D. Le vanadium comme element oligosynergique pour l'Aspergillus niger. Inst. Pasteur (Paris) Ann. 68: 226-244. 1942.

23. Allen, M. B. Sci. Monthly 83: 100-106. 1956.

24. Arnon, D. I. and G. Wessel. Vanadium as an essential element for green plants. Nature (London) 172: 1039-1040. 1953.

25. Arnon, Daniel I. The role of micronutrients in plant nutrition with special reference to photosynthesis and nitrogen assimilation. Trace Elements, Proc. Conf. Ohio Agr. Exp. Stat., Chap. 1. 1958.

the maximal level of the Hill reaction in photosynthesis by isolated chloroplasts was raised by the addition of vanadium.

Bechi(26) was the first (1879) to mention the existence of vanadium in the ashes of plants. There is considerable literature dealing with the methods and techniques for testing the amounts of vanadium in soils, and in plant and animal tissues. I shall only indicate some of the critical species which seem to have high percentages of vanadium in their tissues.

Among the fungi in 17 species tested, Amanitopsis muscaria showed from 60.8 to 181 ppm. in seven lots tested. Other species of some note are: Lactarius torminosus (12), Amanitina phalloides (2.4) ppm.), Amplariella spissa (1.0 ppm.) and Aspidella solitaria (1.8 ppm.), as recorded by Bertrand(8).

Czapek(27) found vanadium in the ash of red beets, sugar beets, grape vines, Fagus, Quercus, Picea, Abies and Carpinus. Cannon(7) presented an extensive study of the ash from plants collected in the Colorado Plateau region where there are large deposits of vanadium. It was found that plants absorb considerable quantities of vanadium through their roots and store some there, but do transfer some to the twigs and leaves. The leaves of plants rooted in ore contained from 40 to 200 ppm. as vanadium oxide, as compared to those of plants collected from barren sandstone and shale (which contained from 20 to 40 ppm. vanadium oxide). Among the plants studied, Astragalus pattersonii (12 ppm.), A. preussii arctus (3000 ppm.), A. confertiflorus (90 ppm.), Oryzopsis hymenoides (70 to 690 ppm.) and Stanleya arcuata (65-120 ppm.) also store up large quanties of selenium. Other plants that stored vanadium were: Atriplex confertifolia (10-90 ppm), A. canescens (25-30 ppm), Bahia nudicaulis (70 ppm.), Chrysothamnus viscidiflorus (50-200 ppm.), Artemisia spinescens (70 ppm.), Haplopappus armeroides (260 ppm.), Sarcobatus vermiculatus (400 ppm., roots) and Cowania mexicana (50-75 ppm. during the dormant period; 400 ppm. during the active period). In some trees and shrubs studied, the following ppm. of vanadium were observed; Ephedra viridis (70 ppm), Fraxinus anomala (5 ppm.), Juniperus monosperma (10-60 ppm.; 140-4000 ppm. in roots), Pinus edulis (about 10 ppm). and Quercus gambellii (5-90 ppm.; 1700 ppm in roots). A Spirogyra sp. showed 500 ppm.

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26. Bechi, E. Nuove richerche del boro e del vanadio. Atti Roy. Accad. Lincei, III, 3: 186. 1879.

27. Czapek, Fr. Biochemie der Pflanze, 2 Aufl. II. Bd. 1920. Jena.

Bertrand(28-30) reported vanadium in every sample of 62 species of plants studied. Most of the fungi had less than 0.5 ppm., except *Amanita muscaria* which is believed to live on the roots of conifers; it had 112 ppm. vanadium. Root nodules of most legumes had 3-4 ppm.; *Vicia faba* root nodules had 12 ppm. vanadium. Bertrand(8) presented a correlation study of the vanadium intake for six lots of legumes:

	Soil y-vanadium	Roots ppm.	Nodules ppm.	Aerial ppm.
Kidney bean	19.4	38.0	27.2	5.6
Black Tokyo Soya	23.7	27.6	32.6	5.2
Yellow lupine	54.3	24.2	21.5	12.8
White lupine Vendee	54.3	56.0	20.4	5.3
White lupine Versailles	23.7	25.8	27.8	2.97
Broad bean	32.0	75.0	48.5	4.4

Demarcay(31) reported vanadium in the ashes of *Pinus sylvestris*, *Picea*, *Quercus*, *Vitis*, *Populus* and *Carpinus*. Robinson, Steinkoening and Miller(32) found vanadium in six of the 50 plants studied, and reported most notable: kidney beans, sugar beets, pine needles and clover. However, Dimetriev(33) found that vanadium

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28. Bertrand, D. Recherches sur le vanadium chez les végétaux. Inst. Pasteur (Paris), Ann. 68: 58-68. 1942.

29. Bertrand, D. Distribution of vanadium in plants. Bull. Soc. Chim. Paris, V, 9: 121-133. 1942.

30. Bertrand, D. Vanadium in fungi, especially *Amanita*. Bull. Soc. Chim. Biol. 25: 194-197. 1943.

31. Demarcay, E. Sur la présence dans les végétaux du vanadium, molybdènem et du chrome. Compt. Rend. Acad. Sci. Paris, 130: 91-92. 1900.

32. Robinson, W. O., L. A. Steinkoening and C. F. Miller. The relation of some of the rarer elements in plants and soils. Bull. U. S. Dept. Agr., No. 600: 1-25. 1917.

33. Dimetriev, K. S. The effect of microelements in limed podzol soils on the development and the crop of red clover. Pedology (USSR), No. 4: 114-133. 1939: Klim. Referat. Zhur., No. 11: 54. 1939.

had no effect on the development and growth of red clover in limed podzol soils of Russia. The presence of vanadium and other rarer metals in the soils of Russia have been reported by Vinogradov and Bergman(34) and by Arinushkina and Levin(35). It is in such regions of southern Russia that Cleome ornithopodioides Linn. grows naturally. It would be of interest to know whether or not this and other species are found only in relation to vanadium-carrying soils in Russia.

Vanadium has been studied in the soils of Argentina by Trelles and Amato(36), and its action on plant growth in Argentina was studied by Ramirez(37). In Hawaii this element in the soil was studied by Nakamura and Sherman(38). Riccardi(39) found 9.5 to 36.5 ppm. of vanadium in the lava of Mt. Etna; he also found that plants that grew in the lava of this volcano contained appreciable quantities of the element.

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34. Vinogradov, A. P. and Bergman, G.G. Chromium and vanadium in soils of the Soviet Union. Pochvovedenie, 1949; 569-573. Oct. 1949.

35. Arinushkina, E. V. and Levin, F. I. Content of vanadium, chromium, manganese, cobalt and nickel in the soils of the Agrobiologicheskaya Stantsiya of Moscow Gosudarstvennyi Universitet. In N. S. Avdonin, Povyshenie plodorodiya pochv nechernozemmoi polosy 1: 69-79. 1961.

36. Trelles, R. A. and Amato, F. D. Arsenico, vanadio y molibdeno en suelos y en algunos estratos de la Republica Argentina. Soc. Cient. Argentina An. 149: 93-107. 1950.

37. Ramirez, E. C. Vanadium and its action on plant growth. Am. Sci. Quim. Argentina 2(6): 145-146. 1914.

38. Nakamura, M. T. and Sherman, G. D. The vanadium content of Hawaiian Island soils. Hawaii Agr. Expt. Sta. Tech. Bull. 45: 1-20. 1961.

39. Riccardi, L. Sulla diffusione del vanadio nel regno minerale e vegetale. Atti Accad. Gioenia di Sci. Nat. Catania 17: 161-166. 1883.

40. Shibuya, K. and H. Saeki. Effect of vanadium on growth of plants. Jour. Soc. Trop. Agr. Japan 6: 721. 1934.

Shibuya and Saeki(40) studied the effect of vanadium on the growth of plants in Japan. While studying the effect of molybdenum on plants in nature, Ter Meulen(41) found that Amanita muscaria had 3.3 ppm. vanadium, garlic had 0.8 ppm., but that onions had none.

Although there is still no proof that vanadium is an essential micronutrient element in the plant kingdom, there is some evidence that in some lower plants and in a few higher plants, vanadium helps in the physiological activities of those plants. Mere traces seem to accelerate growth activities, as in Scenedesmus, Aspergillus, Azotobacter, and various higher plants. Warington(42-44) has studied the interrelationships between vanadium and other microelements in the nutrition of soybean, flax, oats, and peas, and has shown that there is an increase in the toxicity of molybdenum with an increase of vanadium, especially in soybean and flax, at least when using solutions of $VOCl_2$ up to 10 ppm. Mazé and Mazé(45) indicated that vanadium was favorable to corn, but did not prove that it was a necessary nutrient element for good growth in that plant.

Our studies of the effect of vanadium salts on the growth of microorganisms and the higher plants started with the work of

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41. Ter Meulen, H. Sur la repartition du molybdene dans la nature. Rec. Trav. Chim. Pays-Bas 50: 491-504. 1931.

42. Warington, Katherine. Some interrelationships between manganese, molybdenum and vanadium in the nutrition of soybean, flax and oats. Ann. Appl. Biol. 38: 624-641. 1951.

43. Warington, K. The influence of iron supply on toxic effects of manganese, molybdenum and vanadium on soybean, peas and flax. Ann. Appl. Biol. 41: 1-22. 1954.

44. Warington, K. Investigations regarding the nature of the interaction between iron and molybdenum or vanadium in nutrient solutions with and without a growing plant. Ann. Appl. Biol. 44: 535-546. 1956.

45. Mazé, P. and Mazé, P. J. Recherches sur la nutrition minerale des végétaux superiéurs. Compt. Rend. Soc. Biol. 132: 375-377. 1939.

Witz and Osmond in 1886(46). The concensus of opinion from the investigations up to date is that vanadium in concentrations up to 10 to 20 ppm. seems to be stimulatory, whereas higher concentrations prove toxic to most higher plants. Cleome ornithopodioides Linn. seems to be one of the higher plants which not only can tolerate high concentrations of vanadium in the soil, but which seems to need vanadium to grow properly. It will be of interest to note what other plants move in on the vanadium-slag pile in Canton.

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46. Witz, G. and Osmond, F. Essai sur l'application des propriétés de l'oxycellulose au dosage du vanadium. Bull. Soc. Chim. Paris 45: 309-314. 1886.

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BOOK REVIEWS

Alma L. Moldenke

"Orchids of the Western Great Lakes Region", by Frederick W. Case Jr., xii + 148 pp., illustr. Cranbrook Institute of Science, Bloomfield Hills, Michigan. 1964. $7.00

The Cranbrook Institute has rendered another valuable service to science in publishing this attractive, useful and accurate survey by an author who has carried on years of devoted field work, systematics, and culture studies to these fascinating plants.

The book begins with a brief description of the Orchidaceae, an ecological explanation with a plea for conservation, a detailed treatment of the nine typical habitats of this region, each with species lists, and methods of growing orchids. "At present the Great Lakes region is especially favorable to orchids because of its geographic position, its lake-influenced climate, its soil types, and its glacial history. Fifty-one orchid species grow in the region, besides a number of distinct varieties within the species and a number of hybrids. This region surpasses all others in temperate North America, except neighboring New England, in the number of its orchid species. Yet not one of these species is indigenous to the region. With the possible exception of a very few species in the unglaciated driftless area of Wisconsin, all of our orchids have migrated from other regions since Pleistocene glaciation about 10,000 years ago."

The book continues with excellent keys to genera, with descriptive text for each. Then there are clear cut keys to each species, each illustrated with critical line drawings and each described ac-